Estimates of large-scale vertical velocities in the tropical Atlantic Ocean.

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Introduction

Vertical velocities in the ocean are several orders of magnitude smaller than horizontal velocity field, for this reason, direct observations of $\boldsymbol{w}$ in the ocean have not been possible. The only way to estimate vertical velocities is through a theoretical approach. The simple Linear Vorticity Balance (**LVB**) has been used to find out to what extent it can describe the large-scale dynamics of the Atlantic vertical velocity in simulations of the NEMO OGCM. The LVB dominates the circulation in the interior of the tropical and subtropical gyres below the mixing layer, with very promising results in the deep ocean. This study has made it possible to explain how upwelling and downwellings are related to meridional flow and in particular to βv term of the LVB.

Objectives

- **Validity** of the **LVB** in the tropical Atlantic Ocean.
- **Estimation** of the **w** in the ocean interior.
- **Relation** between **horizontal** and **vertical** movements.

Data and methods

Data

We have used the OCCIPUT simulation of the OGCM NEMO during the 1960-2015 period from Bessieres et al., 2015 with ¼ degree horizontal resolution (1442 x 1021 grid points) and 75 vertical levels. This simulation uses the DFS5.2 forcing (Dussin et al., 2015).
We compute the temporal mean of the period to study the ocean at large scale.

Linear Vorticity Balance (LVB)

Linear Vorticity Balance (LVB) is the linearization of the Vorticity Equation obtained by the curl of the horizontal continuity equations.
We study the validity of the LVB computing the relative error between the LVB terms following previous studies (Ndoye, 2011 and Thiam, 2020).

Eq. 1.

$$\beta v = f\frac{\partial w}{\partial z}$$

→ **Integration** of LVB to estimate $\boldsymbol{w}$ at each depth.

Eq. 1. LVB equation where $\boldsymbol{f}$ is the Coriolis parameter, $\boldsymbol{\beta}$ is the latitudinal variation of $\boldsymbol{f}$, $\boldsymbol{v}$ is the meridional component of the horizontal velocity and $\boldsymbol{w}$ is the vertical component of the velocity.

Spatial filter

This study is interested in large scale circulation, based on the balance of the geostrophy. It is neccessary to filter out small scales.
It has been applied a space filter that depends on the coastine: the weight of each grid point in the spatial running mean is smaller near the coast.

- **Vortex streaching term ($\boldsymbol{f\partial w/\partial z}$)** two times space filtered → First: eliminate noise from the grid computation. Second:Eliminate small scale.
- **$\boldsymbol{\beta v}$ term** → One time: Eliminate small scale.

Results

LVB validity

The **LVB** dominates the circulation in the interior of the **tropical** and **subtropical** gyres. The LVB is no longer valid in the equatorial band.

The spatial filter allows to eliminate the small scale and to increase the LVB valid area. The meridional section allows to see LVB behaviour at all depts.

We get surprisingly good results of the validity of the LVB in the abyssal ocean.

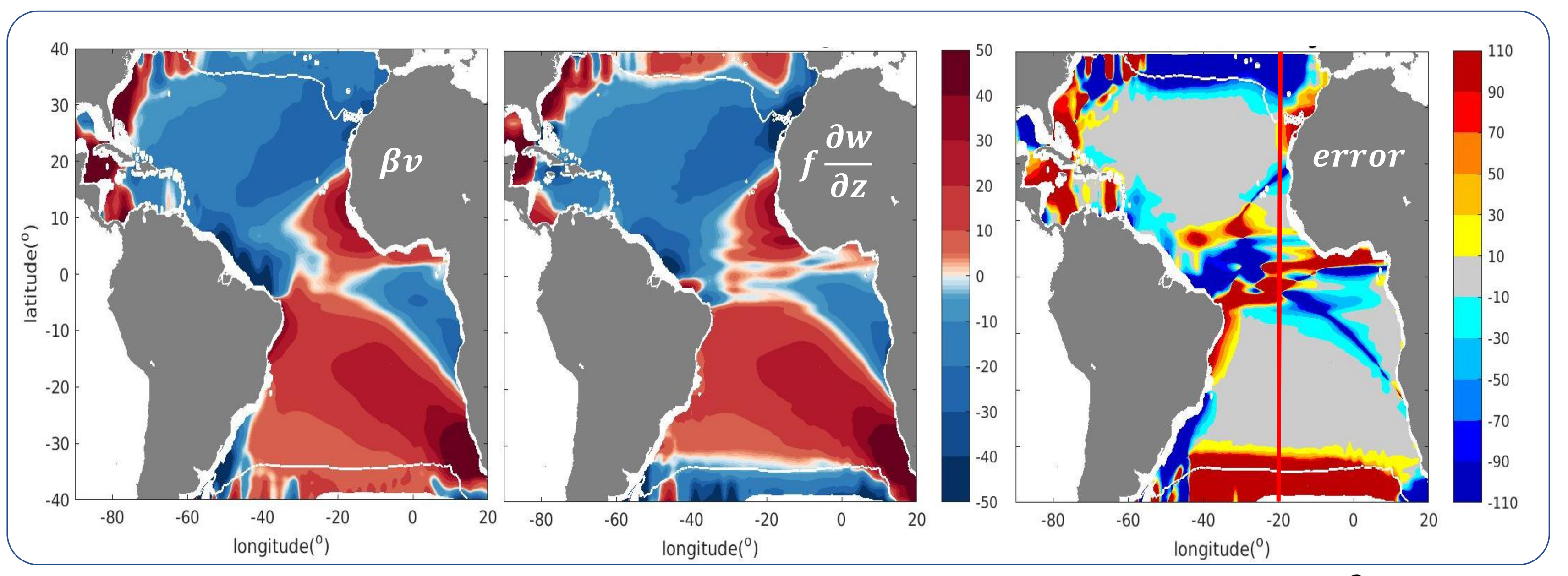


Fig. 1. Low pass filtered LVB term and relative error at lower thermocline ($26\ \mathrm{kg/m^3}$).

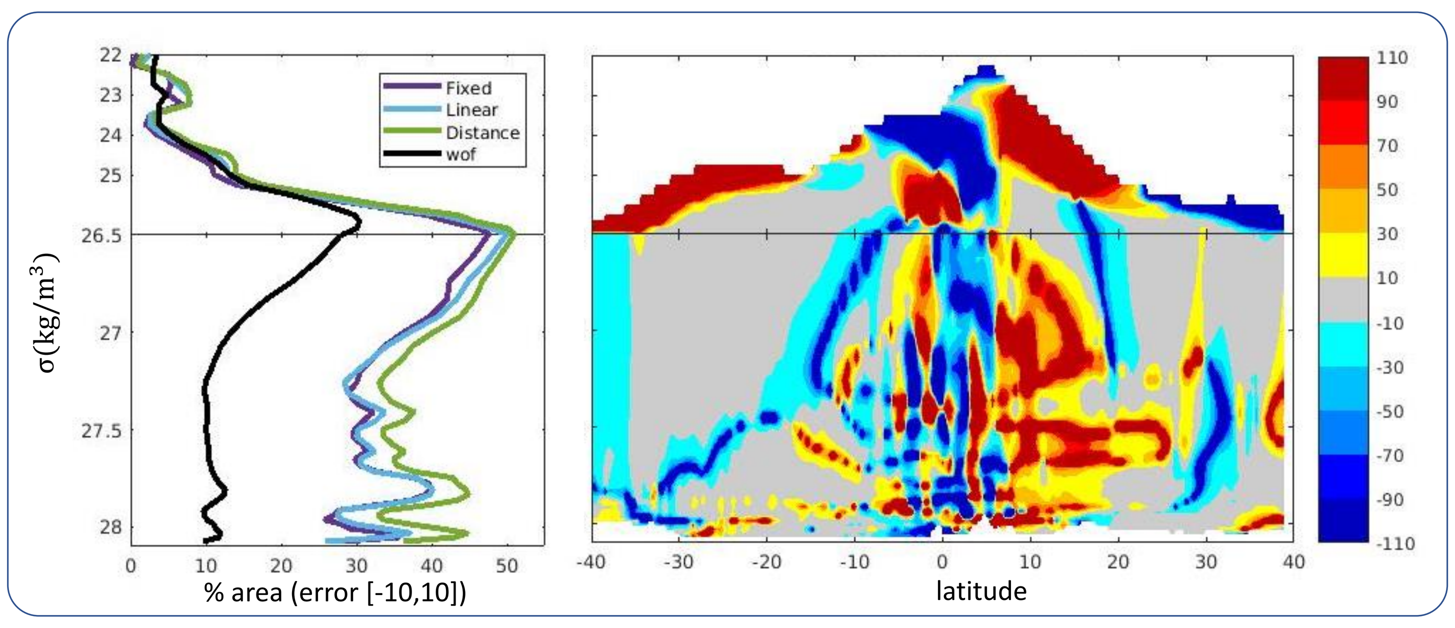
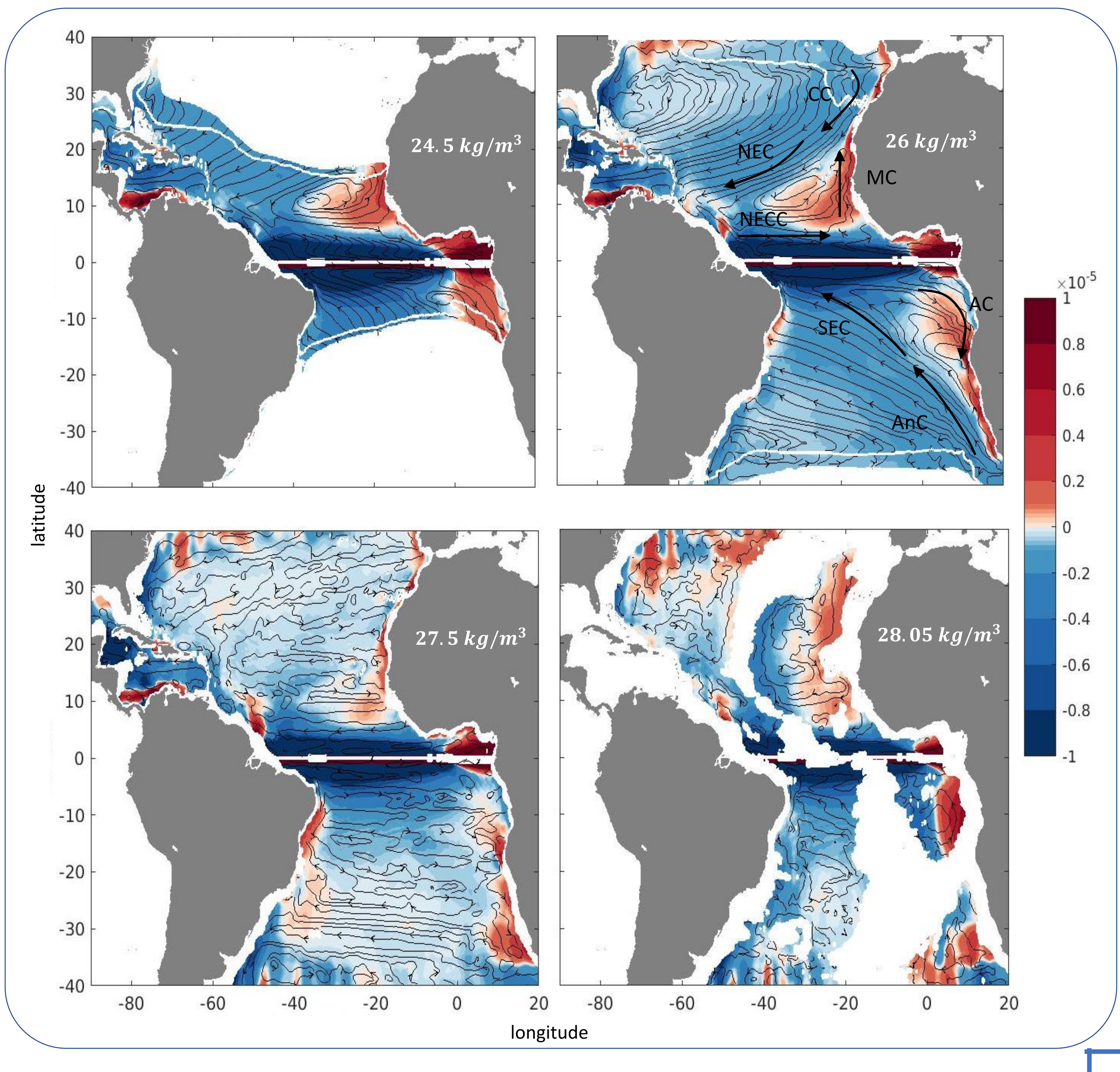


Fig. 2. (left) Percentage of LVB valid area and (right) low pass filtered LVB relative error at 20^{o}W meridional section.

$\boldsymbol{w}$ estimation



Computing **Ekman pumping** vertical velocity from NEMO wind stress and using it as boundary condition at surface and **integrating** in depths:

$$w(z') = w_{Ek} - \int_{z'}^{0}\frac{\beta v}{f}dz$$

Eq. 2. LVB integration.

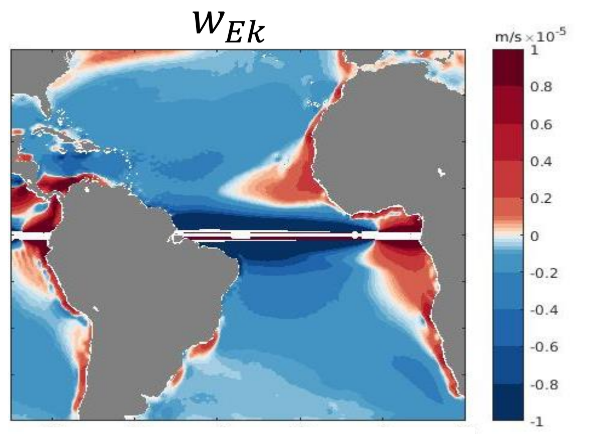


Fig. 3. Ekman pumping vertical velocity computed from NEMO wind stress output.

Using the $\boldsymbol{w}$ **estimation** we can apreciate a relation between the horizontal circulation and the sign of the vertical velocity field:

- If v is **poleward**, it is convergent and w is negative (**downwelling**).
- If v is **equatorward**, it is divergent and w is positive (**upwelling**).

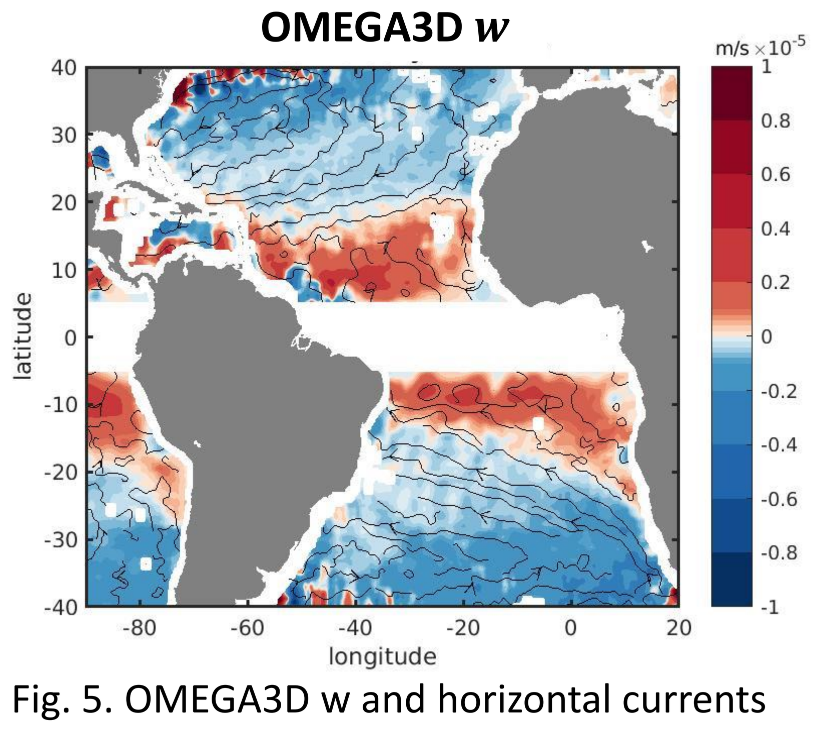
Equatorward currents diverge and absorve water mass from the Ekman layer, generatng downwelling movements. Poleward currrents converge water masses that feed local upwelling.

*

Poleward currents	Equatorward currents
MC	NEC
	CC
AC	AnC
	SEC

Fig. 4. w estimation from Eq. 2. and horizontal currents streamlines in m/s at 24.5, 26, 27.5 and 28.05 $\mathrm{kg/m^3}$ isopycnal levels.

OMEGA3D comparison



The representation of the observation-based vertical velocity field (**OMEGA3D**) estimated from omega equation from Buongiorno Nardelli, 2020 doesn't represent correctly the w sign pattern estimated from the LVB in this study. Buongiorno Nardelli, 2020 says that OMEGA3D $\boldsymbol{w}$ display higher values than other observation based reconstructions in the intertropical band.

Fig. 5. OMEGA3D w and horizontal currents streamlines in m/s from Buongiorno Nardelli, 2020.

Conclusions and future perspectives

- **LVB** is **valid** in the Tropical Atlantic:
  - **Subtropical** and **tropical** gyres interior (far from WBCs and equator band).
  - **Intermediate** ocean.
  - **Abyssal** plains.
- **Improvement** of **LVB valid area** using a **spatial filter**. Filtered out the scale smaller than 8^{o}.
- **Estimation** of the $\boldsymbol{w}$ using $\boldsymbol{w_{Ek}}$ as boundary condition at surface.
- **Demonstration** of the link between **horizontal** and **vertical** movements.

Future perspectives

- Use of **non linear terms** of the Vorticity Equation in the areas where the **LVB** is **not valid**.
- Reconstruct $\boldsymbol{w}$ using **LVB** with **OMEGA3D horizontal velocity field** output and compare with our $\boldsymbol{w}$ estimation.

* MC: Mauritanian Current
AC: Angola Current
AnC : Angulas Current
CC: Canary Current
NEC: North Equatorial Current
SEC: South Equatorial Current

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